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From: Advanced Sonar Division

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Subj: Semi-annual Performance Report on "Physics of Buried Mine Detection and Classification," under on Grant No. N00014-94-1-0485, for the Period 1 March 1994 through 31 August 1994

Ref: (a) Office of Naval Research Grant No. N00014-94-1-0485, "Physics of Buried Mine Detection and Classification"

Encl: (1) Semi-annual performance report
(2) Material Inspection and Receiving Report (DD Form 250) ASG0266

1.   Enclosure (1) is submitted in compliance with Ref. (a) as the semi-annual performance report.

2.   Enclosure (2) is forwarded as required by DFARS, Appendix F, Distribution for the Material Inspection and Receiving Report. Please sign and return one copy to the address shown above, marked for the attention of the Contracts Office. A signed DD Form 250 is necessary for ARL:UT to maintain complete documentation files on the delivery of contractually required items.

Nicholas P. Chotiros

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13. ABSTRACT (Maximum 200 words)

A better understanding of the science and engineering of buried mine detection in (1) offshore and (2) surf zone sediments, leading to safe, standoff detection technologies. This project is part of a leveraged investment program for ONR and ARPA offices, which involves SPECWAR and USMC interests, to pursue major research thrusts already begun by the authors, that will lead the way to systems development. The work is further leveraged by the cooperation of the SACLANT Undersea Research Center (SACLANTCEN), which will provide cooperating seafloor scientists, research tools and research vessels in a joint effort to research the basic Physics of the governing processes.

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Semi-Annual Performance Report
Grant No. N00014-94-1-0485
1 March 1994 - 31 August 1994

Principal Investigators: Drs. Nicholas P. Chotiros and Thomas G. Muir

Title of grant: Physics of Buried Mine Detection and Classification

Category of Research: Surface and volume scattering

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Long-term goals:

A better understanding of the science and engineering of buried mine detection in (1) offshore and (2) surf zone sediments, leading to safe, standoff detection technologies. This project is part of a leveraged investment program for Office of Naval Research (ONR) and Advanced Research Projects Agency (ARPA) offices, which involves SPECWAR and US Marine Corps interests, to pursue major research thrusts already begun by the authors, that will lead the way to systems development. The work is further leveraged by the cooperation of the SACLANT Undersea Research Centre (SACLANTCEN), which will provide cooperating seafloor scientists, research tools and research vessels in a joint effort to research the basic Physics of the governing processes.

Scientific or technological (S&T) objectives:

(1) Theoretical understanding and modeling of the Biot slow wave and the leakage wave for exploitation in the detection and classification of buried targets.

(2) A seismic interface wave sonar concept, for the detection and classification of buried and proud mines in the surf zone

Background:

The detection of buried mines remains an unsolved problem in offshore sediments and in the surf zone. Optical techniques are useless because they cannot penetrate sediments while magnetic techniques are of low value because of low resolution, short range, and the introduction of non-magnetic mines. (1) With respect to buried mines in the off-shore sediment, it is desired to have long range systems, operating at low grazing angles for maximum standoff distance. On the basis of viscoelastic theory, it has long been thought that there is a critical grazing angle that precludes penetration at low grazing angles into most unconsolidated sediments. However, this conclusion has been shown to be erroneous. (2) In the surf zone, extensive clouds of micro bubbles generated by collapsing wave processes scatter and attenuate acoustic frequencies capable of penetrating the sediments. Avoiding the opacity of bubble zone scattering may require seismic sonar methods, in which Sholte waves are generated in the sediment and used to echo range off buried targets.

Approach:

(1) Mines buried in offshore sediments. Due to the availability of scientific knowledge, theory, models, and research tools developed at ARL:UT in prior year efforts sponsored by Naval Research Laboratory (NRL) and ONR, we were able to initiate research at the forefront of the field, without the normal start up time required to "come up to speed". The emphasis was on sand since it supports all three types of waves, the Biot fast, slow and shear waves. The ARL:UT Biot model of acoustic penetration has been found to agree with in-situ data in the 10-100 kHz band. The objective for FY94 was to verify and extend the range of the ARL:UT Biot model into the 1-10 kHz band. There were strong trend changes in this band that severely tested the validity of the model.

(2) Mines buried in the surf zone. The Sholte wave is a seismo-acoustic interface wave that travels very slowly in unconsolidated sediments. Since these waves are highly attenuated, low frequency operation is required. Due to the conduct of prior years efforts in Anti-Submarine Warfare (ASW) seismo-acoustics at SACLANTCEN and at ARL:UT (sponsored by ARPA Marine

Systems Technology Office (MSTO)), considerable experience, research tools, testbed sites, and computational models were brought to bear on the development of the seismic interface wave sonar concept described above, without much need for "start up time development". Although a new target strength theory was needed for this specialized problem, it was facilitated by previous theoretical developments at the participating organizations. Similar considerations apply to the new experiments that were done to develop the concept.

Accomplishments and results:

(1) Offshore buried mine problem. An experiment was conducted by SACLANTCEN in cooperation with ARL:UT to measure sound propagation into a sandy sediment. A hydrophone array was planted in a sandy sediment, at a water depth of 10 m, in the Gulf of the Poets, Lerici, Italy, from the SACLANTCEN research boat, R/V Manning. A sparker was used to transmit sound waves towards the hydrophone array. The analysis is still in progress, but a number of observations may be made about the received signal at shallow grazing angles. The first arrival is the evanescent wave, followed by downward propagating slow waves, as shown in Fig. 1. Then, there is a period when there are several waves traveling in a variety of directions that may be attributed to a modal structure. Upward traveling waves, probably refracted within the sediment or reflected from deeper strata, bring up the rear. The slow wave speed at 1 kHz is preliminarily estimated to be approximately 700 m/s. (2) Surfzone buried mine problem. The first round of experiments with an interface-wave sonar accomplished several goals:

1.   They proved seismic interface wavers could be excited in the sediment, preferentially, over ordinary compressional waves, and that the seismic interface waves propagated along the sediment interface bordering either water or air.

2.   They provided medium characterization in a realistic environment, an un-prepared natural beach. The relative importance of trapped and leaky Sholte modes and the influence of dispersion have now been measured, which makes

it possible to engineer a new, specialized second generation of interface-wave transducers.

3.   They demonstrated that not only do pulses of interface waves reflect from buried objects, but they carry a clear signature which can be isolated with signal-processing techniques. These techniques were effectively used to reject noise from remote sources, such as field generators and support equipment in a free-standing mobil deployment. They also made it possible to exploit the high information content of interface waves to combine signal features during target identification.

4.   Finally, they provided a test of the theoretically predicted target strengths. First-round experimental results indicate that the theory, even with minimal assumed knowledge about the environment, provides remarkably good predictions of reflected signal strength and properties.

Impact on S&T, or transition/integration expected:

(1) Offshore problem. Previous attempts at buried minehunting sonar development were less than optimum because of a lack of understanding of acoustic interactions with the ocean sediment. The final result from this project will contribute to the theoretical modeling in support of a new buried mine sonar design. The improved understanding of bottom penetrating acoustics also impacts bottom reverberation modeling and sonar performance models, and will lead to upgrades of models, such as CASTAR, SPM, SEARAY and MINERAY, in the near future.

(2) Surfzone problem. More sonar concepts and configurations can be considered than it was possible to test effectively with first-generation equipment. Even with limited resources, the current experiments provided compelling evidence of their feasibility, and refinements in technique based on what has been discovered will make it possible to test them quantitatively in future implementations.

The work initiated under this ONR grant in FY94 is already beginning to transition to funding for engineering demonstrations at ARPA MSTO, in the

funding of a FY95 Task Description, which includes preliminary 6.2 tasking on this problem.

Relationship to other projects:

(1) Offshore problem. This project has directly benefited from results of previous projects, particularly the NRL high frequency acoustics program and ONR sponsored research projects into Biot's theory.

(2) Surfzone problem. This project is related to and has benefited from seismo acoustic R&D on ASW in shallow water, funded by ARPA MSTO at ARL:UT, under SPAWAR Contract N000-94-1-0082. It is also related to and mutually benefits seismo acoustic research conducted by NATO at the SACLANT Undersea Research Centre, La Spezia Italy.
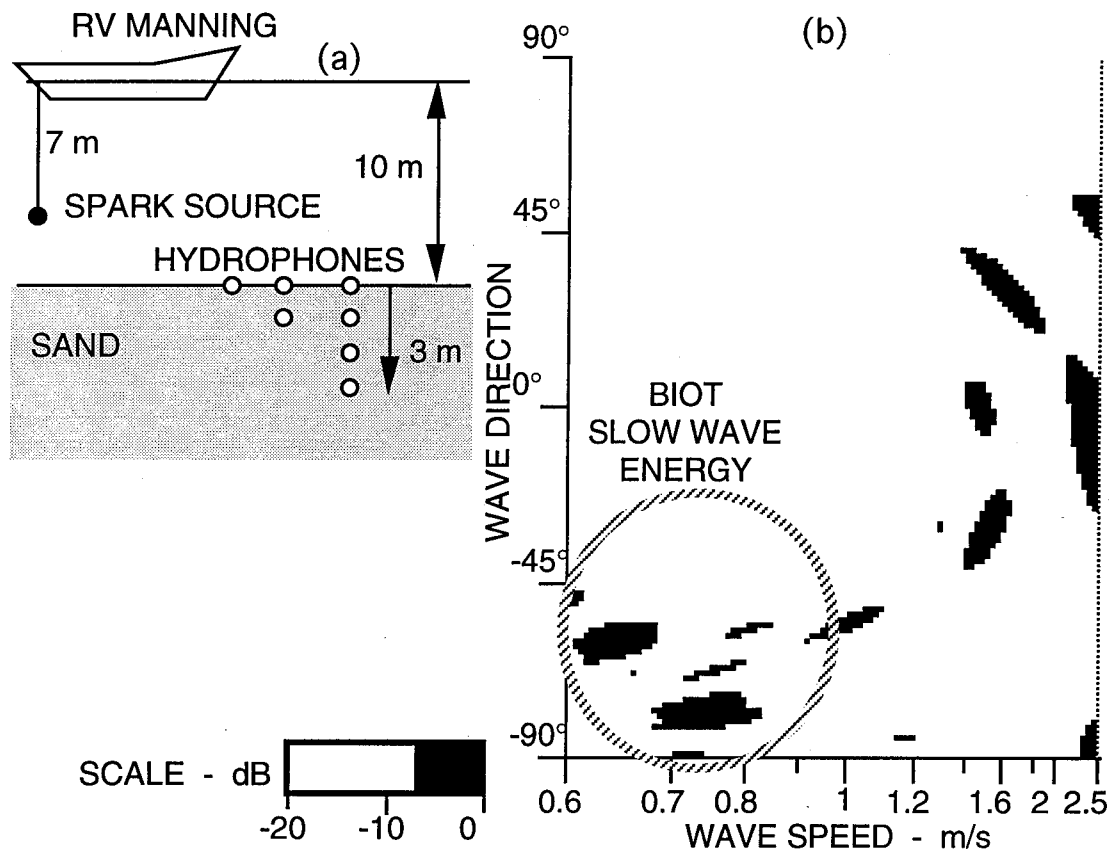
(a) Experiment layout.

(b) An example of processed result from buried hydrophone array showing direction and speed of sediment penetrating acoustic waves.

Fig. 1: Off-shore acoustic sediment penetration